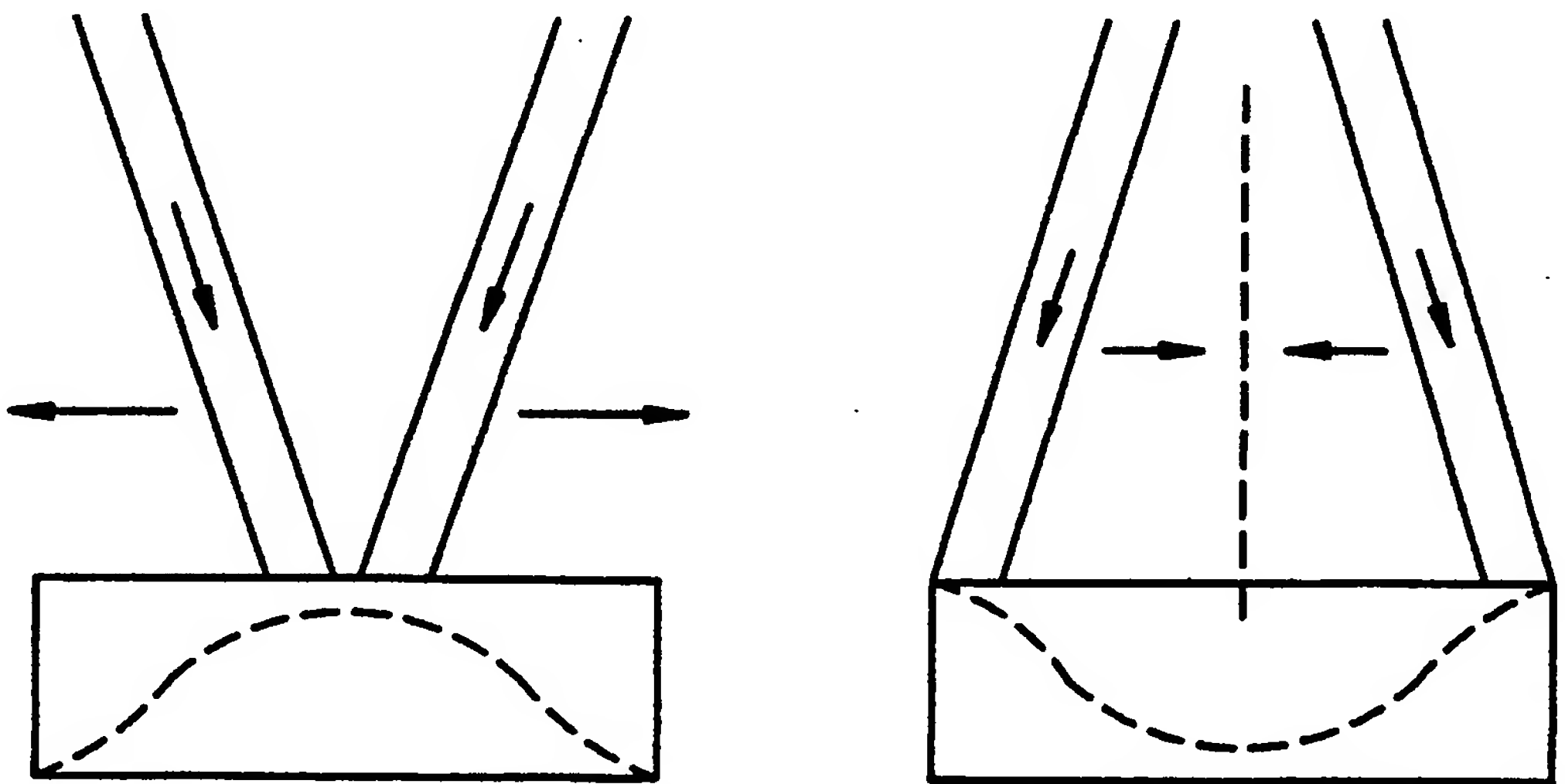




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(21) International Application Number: PCT/US93/06256 (22) International Filing Date: 30 June 1993 (30.06.93) (30) Priority data: 07/954,858 29 September 1992 (29.09.92) US (71) Applicant: BAUSCH & LOMB INCORPORATED [US/US]; Patent Law Department, One Lincoln First Square, P.O. Box 54, Rochester, NY 14601-0054 (US). (72) Inventor: CHAN, Eric ; 610 Fairfield Lane, Austin, TX 78751 (US). (74) Agents: KRASNOW, David, M. et al.; Bausch & Lomb Incorporated, Patent Law Department, One Lincoln First Square, P.O. Box 54, Rochester, NY 14601-0054 (US).		(81) Designated States: AU, BB, BG, BR, CA, CZ, FI, HU, JP, KP, KR, LK, LU, MG, MN, MW, NO, NZ, PL, RO, RU, SD, SK, UA, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>
(54) Title: SYMMETRIC SCANNING TECHNIQUE FOR LASER ABLATION  (57) Abstract Improved methods for modifying target surfaces through ablation which result in a reduction of ablation debris redeposition on the target surface are disclosed.		

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SYMMETRIC SCANNING TECHNIQUE FOR LASER ABLATION

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to the field of laser modification of target surfaces through ablation and methods for smoothing surfaces using lasers as well as targets modified by such ablative techniques.

Background of the Invention

The use of laser beams to modify surfaces is known. In the early 1980's, it was discovered that pulsed lasers emitting in the ultraviolet frequency range could affect a target surface through ablative photodecomposition (APD). Later it was found that by using APD, layers of target material could be removed on the order of about one micron of target material per pulse.

It was further noted that APD did not significantly alter the characteristics of the newly exposed material immediately below the ablated material. This phenomenon has been explained as being due to the UV laser providing enough energy in a short enough period of time to actually break the covalent bonds of the polymeric target materials without heating

the substrate. (See U.S. Patent Nos. 4,417,948 and 4,568,632). Further scanning techniques using APD are disclosed in U.S. Patent No. 5,061,342.

Upon further investigation, it was found that certain materials, when ablated, created varying amounts of debris, some of which was redeposited upon the surface of the target material. It was believed that this redeposited debris somehow frustrated efforts to predictably alter the ablated target surface. Further, it was found that certain materials could not be as cleanly etched as others. A method for ablating a target surface while also removing the deposited and adhered debris from the target surface was not known.

SUMMARY OF THE INVENTION

A novel method to ablate surfaces in a way that simultaneously clears away deposited debris and avoids subsequent debris accumulation has now been determined. To obtain a desired resulting surface on a selected target, the debris formed during the ablation process which becomes redeposited at, and adheres to the target surface must be removed from the target surface before the ablation process continues over the remainder of the target surface.

In accordance with this invention, a method is disclosed for ablating a target surface comprising simultaneously directing a split pulsed beam of UV radiation at said target surface and moving the beams relative to each other and the target surface such that the entire target surface is scanned.

In a further embodiment of the present invention is disclosed a method for photoablating a target surface comprising the steps of a) simultaneously directing a split beam of pulsed UV radiation at the portion of the target surface requiring the least amount of material removal and b) scanning the individual beams of the split beam in a direction away from each other and toward portions of the target surface requiring the greatest amount of material removal such that the entire target surface is scanned.

In still a further embodiment of the present invention is disclosed a method for photoablating a target surface comprising the steps of: a) simultaneously directing a split beam of pulsed UV radiation at at least two opposing edges of the target surface; and b) scanning said beams in a direction toward and stopping at a bisecting line on the target surface such that the entire target surface is scanned.

Further, is disclosed a method for photoablating a target surface comprising the steps of: a) directing a ring-shaped beam of pulsed UV radiation at the edges of the target surface; and b) progressively decreasing the beam radius thereby simultaneously scanning said beam in all directions toward and stopping at the centerpoint of the target surface such that the entire target surface is scanned.

It is further thought that the invention of the present application is especially useful for profiling, crosslinked, thermoset, thermoplastic or other materials including optically clear materials suitable for use as contact lenses.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a depicts a cross-sectional view of a contact lens blank. The dotted line is an exaggeration of the desired final toric surface.

Figure 1b depicts a cross-sectional view of a contact lens blank. The dotted line is an exaggeration of the desired final convex surface.

Figure 2 is a schematic diagram depicting the novel simultaneous split beam scanning technique.

Figure 3 is a perspective view depicting a representative experimental set up for the split beam scanning technique.

Figure 4 is diagram showing a representative experimental set up for the ring-shaped beam scanning technique.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a new method of modifying optical surfaces to produce changes in their spherical, cylindrical or other refractive power, shape factor or other surface geometry. This new method is a modification of the procedures taught in U.S. Patent No. 5,061,342, the entire content of which is incorporated by reference herein.

The method of the present invention employs UV radiation to ablate material from a target surface in order to produce a desired final surface on the target. Suitable target surfaces to be ablated include contact lenses, contact lens blanks, molds used to make contact

lenses, tools used to make such molds, and any means which either directly or indirectly imparts a desired predictable final spherical, cylindrical or other refractive power or geometric shape on an object, such as a contact lens.

Varying amounts of material must often be removed from a target surface to produce a desired end result. For example, to produce toric surfaces on a contact lens, more material must be removed from the edges or periphery of the optical zone than from the central region of the optical zone. (See Figure 1a). Therefore, to produce the toric surface, a significant amount of ablated debris is created at the periphery of the optical zone as compared to the debris created when the central region of the optical zone is scanned and its surface ablated.

Toric contact lenses are understood to be lenses which correct the insufficient visual acuity caused by astigmatism. Such lenses have a cylindric component of refraction, which refractivity is not constant in all planes passing through the optical axis, but has a maximum refractivity in one plane and a minimum refractivity in another plane perpendicular to the first plane.

Lenses with varying power can also be fashioned as shown in Figure 1b wherein less material is removed at the periphery of the optical zone and more material is removed in the center of the optical zone. It is understood to the skilled practitioner in the field that surfaces of any configuration can be produced using the present invention and that the figures presented are for illustrative purposes only.

It was discovered that when the laser beam begins its scan at the edge of a lens to produce toric surface, significant ablated debris was randomly redeposited on the surface of the lens. Some of the debris was redeposited on the lens target in the path of the laser beam scan. When this occurred, as the laser continued its scan, the first material encountered by the beam was not the original target surface, but was the redeposited and freshly adhered debris from the lens periphery.

While the final surfaces created from the so called edge-to-edge scans described in 5,061,342 were often an improvement over other known surface modification procedures, such as lathing, et al., it was believed that the redeposited debris hindered the best results possible.

Therefore, in accordance with the present invention, it is now thought that to create the most efficient result on a target surface, the laser beam scan is initiated at or near the point at which the least amount of material is to be removed to create the final surface. In the case of the toric surface, the least amount of material is removed near the center of the optical zone. (See Fig. 1a).

Therefore, as contemplated by the present invention, Figs. 2 and 3 show a raw laser beam (1) emitted from an excimer laser (2). The raw beam is directed to a beam splitting prismatic lens (3) and may have two beams generated (4 and 5). The two beams are then directed to curved secondary mirrors (6 and 7) which in turn direct the beams to the target surface (8). In one embodiment of the present invention the scanning mirrors (6 and 7) are controlled by a computer means (not shown) to simultaneously affect the beams such that the beams simultaneously move across, and scan the surface of the target. In one embodiment suited to the modification or creation of a toric surface, the beams initially converge at a bisecting line (9) on the target surface and are simultaneously scanned in a direction away from each other toward opposing edges (10 and 11) of the target surface effecting a complete scan of the entire target surface.

In a further embodiment, when it is desirable to remove more material from the center of the optical zone, the beams are initially directed at opposing edges of the target surface, for example positions 10 and 11, and are simultaneously moved toward each other until the two beams converge at a bisecting line on the target surface effecting a complete scan of the entire target surface. (See Fig. 1b).

In a further embodiment, Fig. 4 shows a ringshaped beam capable of expanding and contracting which may be used to simultaneously scan multiple regions of the target surface. Figure 5 depicts such a system especially useful for modifying or creating toric surfaces where, in one embodiment, the raw beam (12) from an excimer laser (13) may be directed to a conical mirror (14) or other mirror capable of producing a ring-shaped beam (15) which is then directed to an annulus secondary mirror (16). The ring-shaped beam is then directed by the secondary mirror to the target surface (17). The diameter of the beam may be progressively increased or decreased by moving the conical mirror relative to the secondary annulus mirror. In one embodiment, the ring-shaped beam may then be directed in its smallest diameter, approaching a point, to the centerpoint (18) of the target surface

and is expanded outwardly, simultaneous extending toward the outermost perimeter of the target surface such that the entire target surface is scanned.

In a further embodiment where more material is to be removed from the central region of the target than from the periphery, the diameter of the ring-shaped beam may be initially set to match the diameter of the outermost perimeter of the target surface. The movement of the conical mirror relative to the secondary annulus mirror then contracts the diameter of the ring-shaped beam resulting in the simultaneous scanning of many points across the target surface such that the beam converges to a minimum diameter at the centerpoint of the target surface and the entire target surface is scanned.

As will be understood by those skilled practitioners in the art, many known reflective (mirrors) or refractive (lenses) optics systems may be used to produce the split beam or ring-shaped beams disclosed herein. The disclosed embodiments are for illustrative purposes only.

Therefore, to achieve the improved ablation results in accordance with this invention, the beam may be scanned in a direction proceeding from the center

simultaneously outward toward opposing edges of the target surface, or from opposing edges simultaneously inward toward a centerpoint or diameter, depending only upon what final results are desired in view of the condition of the initial target surface as already described. It is understood that variations of the present invention may be achieved where intricate or complicated surface configurations are desired.

It is understood that a bisecting line on the target surface is a line extending across the center of the target surface. (The target surface need not be circular or spherical in shape.)

The laser energy applied to a target per unit area is known as the fluence, which for UV radiation is often expressed in terms of millijoules per square centimeter (mJ/cm^2). The fluence range of the laser scanned in accordance with the present invention is preferably from about 20 to about $5000 \text{ mJ}/\text{cm}^2$, is more preferably from about 500 to about $2000 \text{ mJ}/\text{cm}^2$, and is most preferably from about 750 to about $1500 \text{ mJ}/\text{cm}^2$.

A "crosslinked" polymeric material is understood to describe any polymeric material which has any attachment of two chains of its polymer molecules by

bridges comprised of either an element, a group, or a compounds known as crosslinking agents.

The term "thermoset" refers to a polymeric materials which solidify or "set" irreversibly when heated. By contrast, a "thermoplastic" material is understood to refer to a polymer which softens when exposed to heat and is able to return to its original condition.

While the present invention is well suited for the modification of contact lenses, the modification of contact lens buttons, blanks and molds, as well as the tools used to make the blanks, molds and the contact lenses by the present invention is also contemplated. Indeed any means for imparting optical properties to a target surface may be modified by the present invention. The surface modification through laser scanning of such tools used to make the molds which, in turn, are used to make the contact lens, for example, in a cast molding procedure is disclosed in a concurrently filed and commonly assigned U.S. Patent Application identified as Attorney Docket No. P00995.

The present invention is further thought to be useful for other laser scanning applications such as corneal sculpting and other procedures where ablation

debris could conceivably be an obstacle to achieving better target surface quality after scanning.

Many other modifications and variations of the present invention are possible to the skilled practitioner in the field in light of the teachings herein. It is therefore understood that, within the scope of the claims, the present invention can be practiced other than as herein specifically described.

I Claim:

1. A method for ablating a target surface and reducing ablation debris accumulation comprising simultaneously directing a split pulsed beam of UV radiation at said target surface and moving the beams relative to each other and the target surface such that the entire target surface is scanned.
2. A method for photoablating a target surface comprising the steps of a) simultaneously directing a split beam of pulsed UV radiation at the portion of the target surface requiring the least amount of material removal; and b) scanning the individual beams of the split beam in a direction away from each other and toward portions of the target surface requiring the greatest amount of material removal such that the entire target surface is scanned.
3. The method of Claim 1 wherein said beam of pulsed UV radiation is emitted from an excimer laser.
4. The method of Claim 1 wherein said target surface is comprised of a crosslinked polymeric material.
5. The method of Claim 1 wherein said target is a thermoset material.

6. The method of Claim 1 wherein said target is a thermoplastic material.

7. The method of Claim 1 wherein the fluence of said beam of UV radiation is from about 20 mJ/cm² to about 5000 mJ/cm².

8. The method of Claim 1 wherein said target is a contact lens.

9. The method of Claim 2 wherein said target is a contact lens.

10. The method of Claim 2 wherein said target is a corneal surface.

11. A method for photoablating a target surface comprising the steps of: a) simultaneously directing at least two beams of pulsed UV radiation at the edges of the target surface; and b) simultaneously scanning said beams in a direction toward and stopping at a bisecting line on the target surface such that the entire target surface is scanned.

12. The method of Claim 11 wherein said target surface is a contact lens.

13. A method for photoablating a target surface comprising the steps of: a) directing a ring-shaped beam of pulsed UV radiation at the centerpoint of the target surface; and b) progressively increasing the radius of the beam thereby simultaneously scanning said beam in all directions away from said centerpoint to all edges of the target surface such that the entire target surface is scanned.

14. The method of Claim 13 wherein said target surface is a contact lens.

15. A method for photoablating a target surface comprising the steps of: a) directing a ring-shaped beam of pulsed UV radiation at the edges of the target surface; and b) progressively decreasing the beam radius thereby simultaneously scanning said beam in all directions toward and stopping at the centerpoint of the target surface such that the entire target surface is scanned.

16. The method of Claim 15 wherein said target surface is a contact lens.

17. The target surface of Claim 11 wherein said target is an element capable of imparting optical properties or surface geometries on another surface.

18. The target surface of Claim 13 wherein said target is an element capable of imparting optical properties or surface geometries on another surface.

19. The target surface of Claim 15 wherein said target is an element capable of imparting optical properties or surface geometries on another surface.

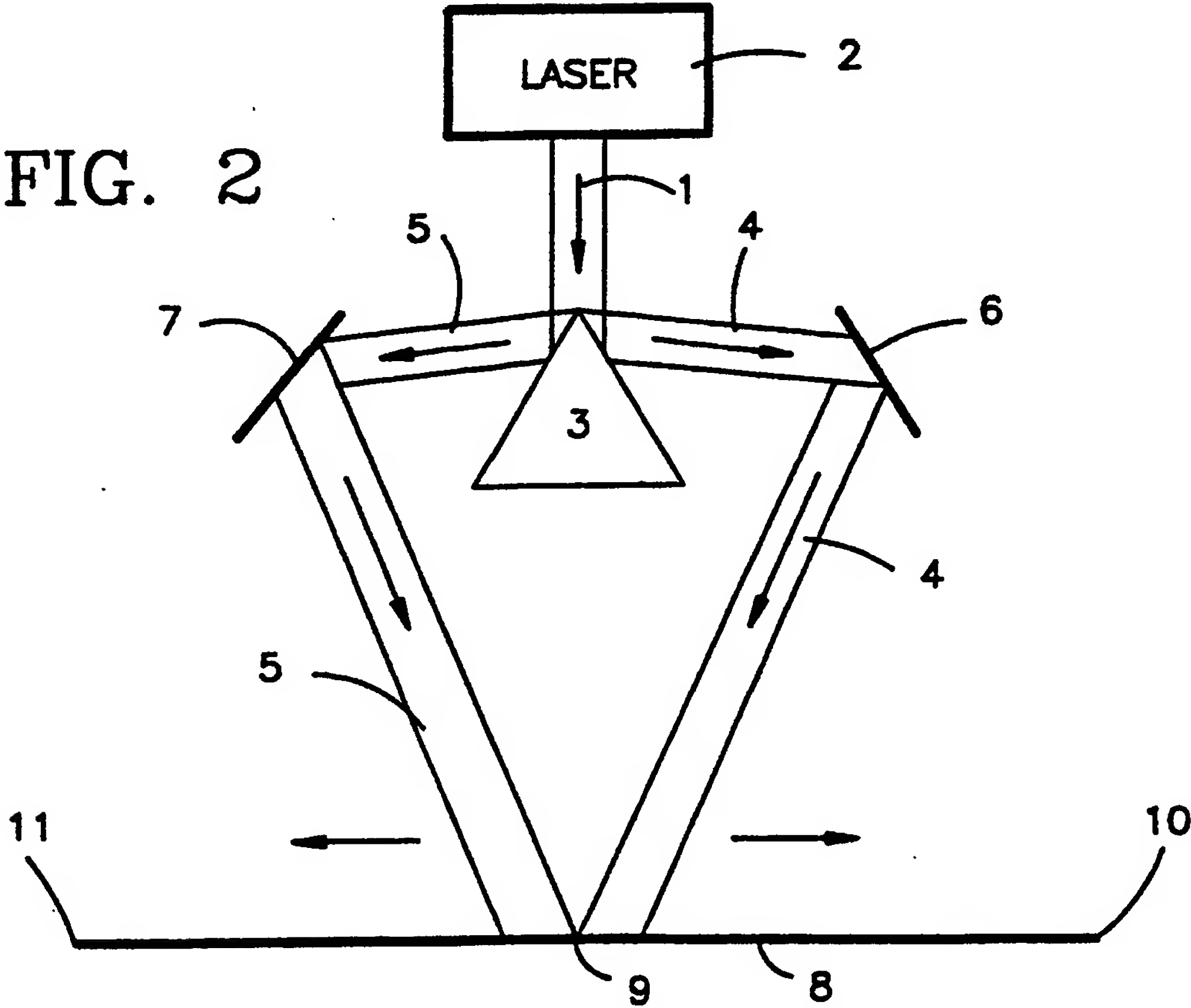
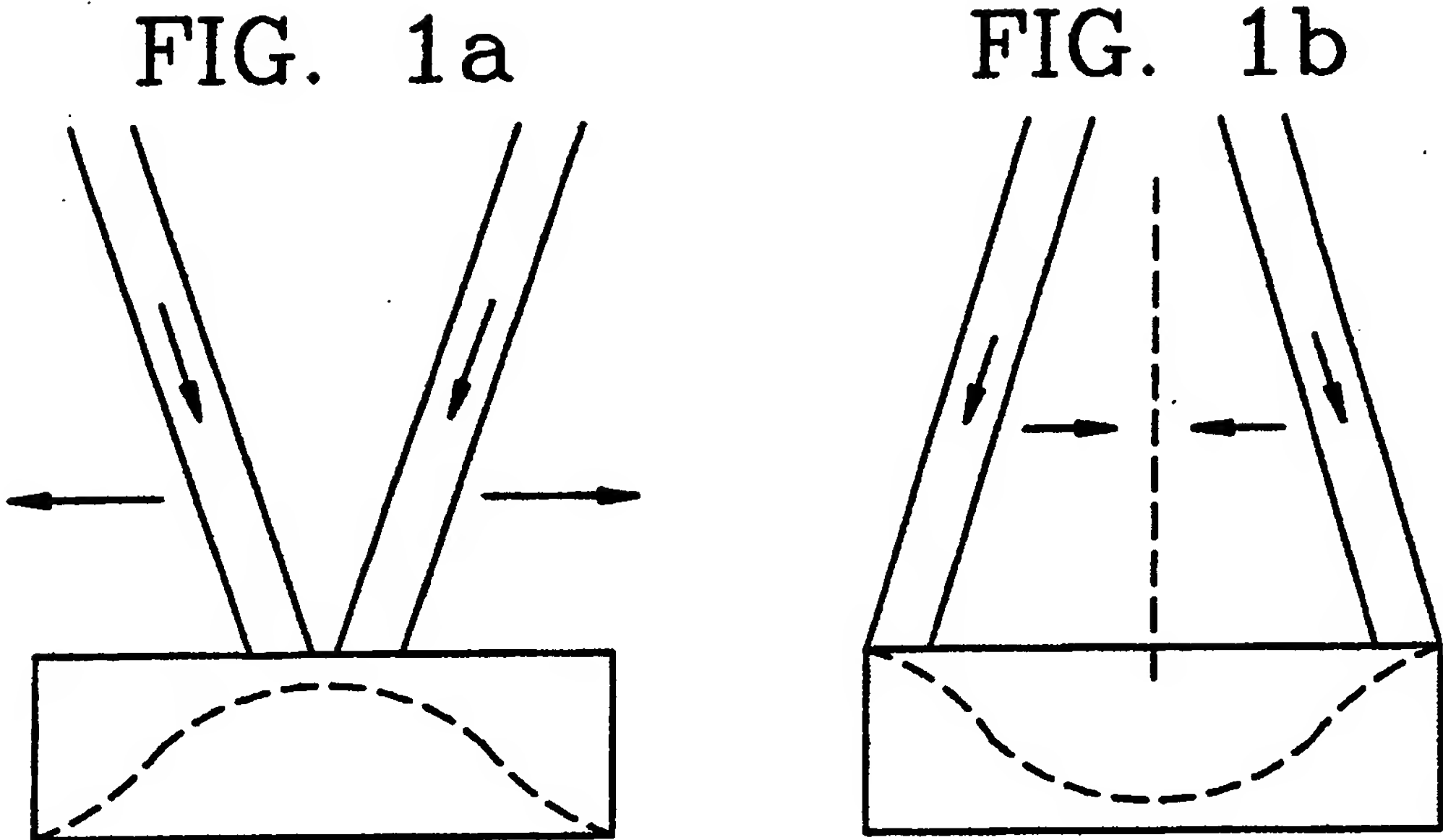
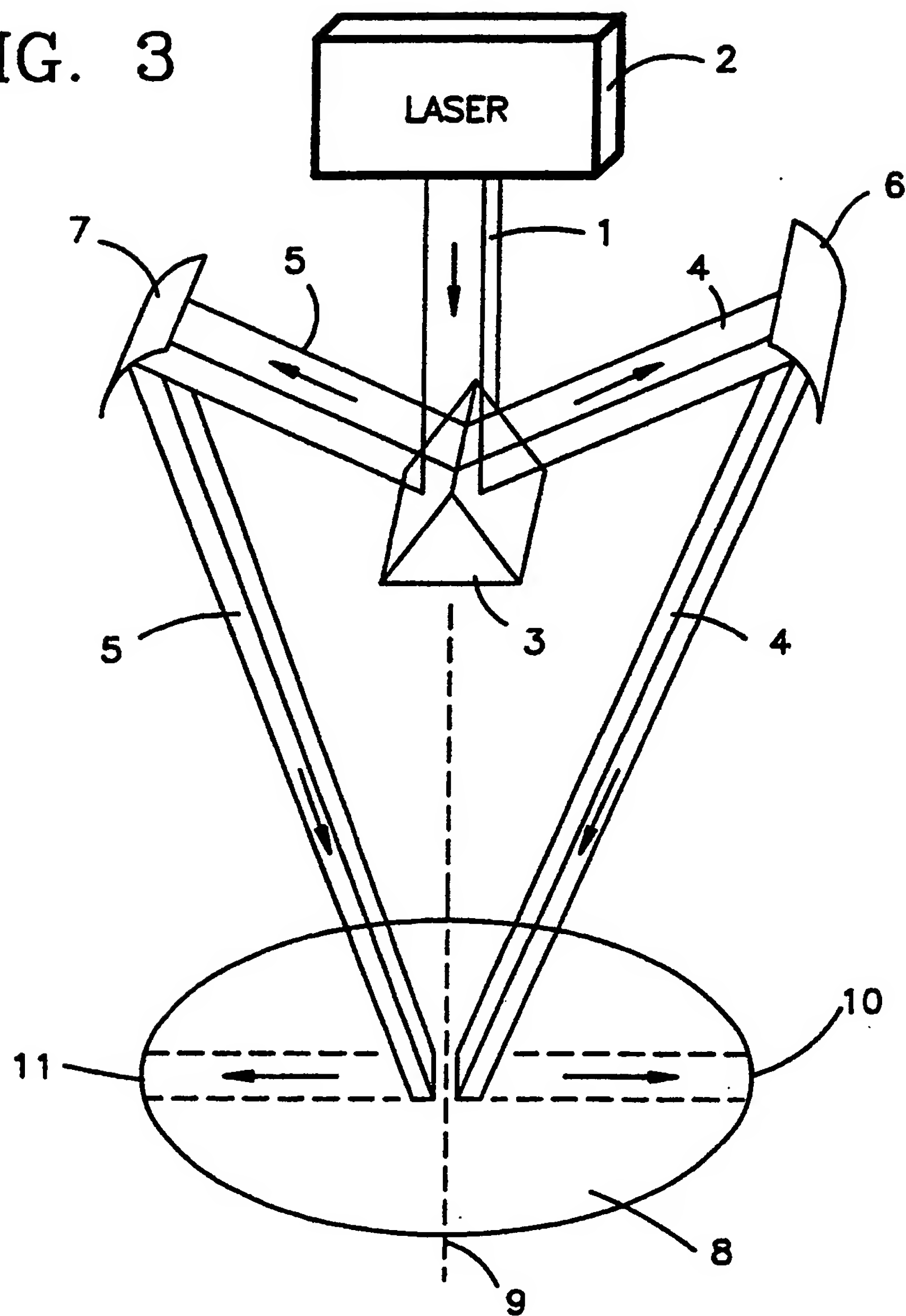


FIG. 3



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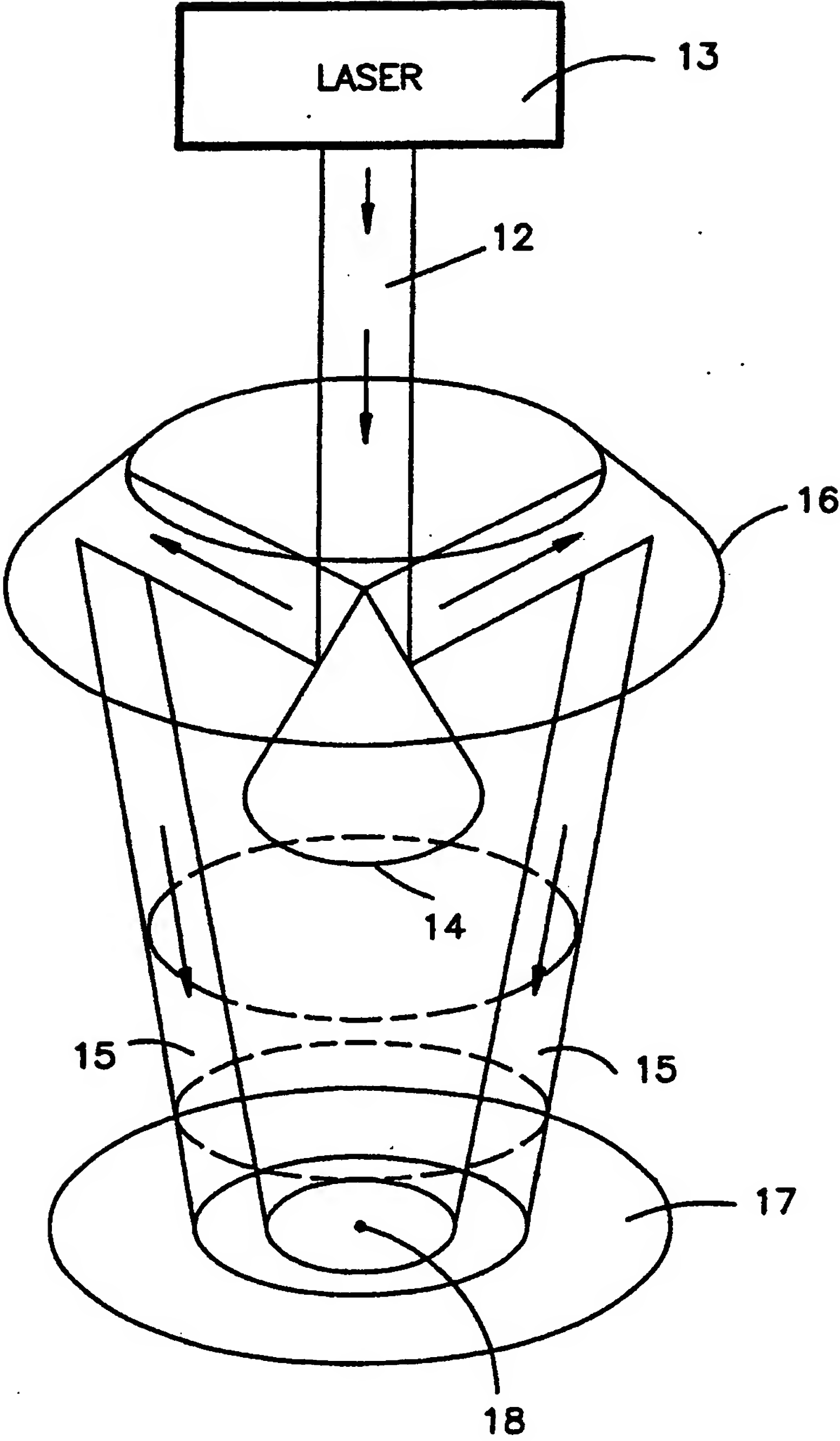


FIG. 4

SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

PCT/US 93/06256

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B23K26/00

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System	Classification Symbols
Int.Cl. 5	B23K

Documentation Searched other than Minimum Documentation
to the extent that such Documents are included in the Fields Searched⁸III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
P, X	WO, A, 9 302 830 (BAUSCH & LOMB INCORPORATED) 18 February 1993 see the whole document ---	1, 2, 4, 6, 8-10, 13-15, 18, 19
P, X	EP, A, 0 525 902 (BAUSCH & LOMB INCORPORATED) 3 February 1993 see the whole document ---	1, 2, 6, 8-10, 13-15, 18, 19
A	GB, A, 2 215 859 (UNITED KINGDOM ATOMIC ENERGY AUTHORITY) 27 September 1989 see the whole document ---	1, 2, 4-19
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¹⁰ Special categories of cited documents:

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search 27 OCTOBER 1993	Date of Mailing of this International Search Report 5 - 11. 93
International Searching Authority EUROPEAN PATENT OFFICE	Signature of Authorized Officer ARAN D.D.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	EP,A,0 291 459 (CIBA-GEIGY AG) 17 November 1988 see the whole document ----	1-4,6-12
A	US,A,4 563 565 (MINESOTA MINING AND MANUFACTURING COMPANY) 7 January 1986 see column 4, line 15 - line 23 see column 5, line 36 - line 39 see column 10, line 26 - column 11, line 2; figures 2,3 see column 11, line 22 - line 33; figure 5 ----	1,2,4-6, 8-19
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**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

US 9306256
SA 77108

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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EP-A-0525902	03-02-93	None	
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